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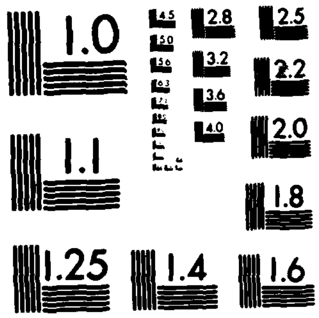

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TECHNICAL REPORT ARAED-TR-86022

SKY SCREEN DATA REDUCTION TO OBTAIN MUZZLE VELOCITY AND LINEAR DRAG COEFFICIENT

CHIU H. NG

AUGUST 1986

US ARMY ARMAMENT MUNITIONS & CHEMICAL COMMAND
ARMAMENT RDE CENTER

U. S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

ARMAMENT ENGINEERING DIRECTORATE

DOVER, NEW JERSEY

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report ARAED-TR-86022	2. GOVT ACCESSION NO. A171 441	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SKY SCREEN DATA REDUCTION TO OBTAIN MUZZLE VELOCITY AND LINEAR DRAG COEFFICIENT		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Chiu H. Ng		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS ARDEC, AED Armament Technology Div (SMCAR-AET-A) Dover, NJ 07801-5001		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS ARDEC, IMD STINFO Div (SMCAR-MSI) Dover, NJ 07801-5001		12. REPORT DATE August 1986 13. NUMBER OF PAGES 23
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Drag
Linear
Projectile
Sky screen
Tank
Velocity
Linear drag

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An analysis and associated computational technique were developed to extract muzzle velocity, velocity decay, and drag coefficient from the sky screen data. This technique utilizes the advantage of a closed form solution to the equation of motion for a flat fire antitank projectile. The only limitation of this technique is that the drag coefficient must be a linear function of velocity. However, the results show that this technique obtains excellent velocity decay even with slight nonlinearity in the drag coefficient.

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CONTENTS

INTRODUCTION

For most of the tank projectile test firings, sky screens are used to obtain the flight time as a function of range. These range data can be used to extract muzzle velocity, velocity decay, and drag coefficient. The most common technique to extract muzzle velocity is to use the difference method to obtain the secant velocities (i.e., $V_{\bar{x}_i} = \frac{x_{i+1} - x_i}{t_{i+1} - t_i}$). The first few secant velocities are then fitted with a straight line or a parabola to obtain the muzzle velocity. There are two disadvantages with this type of data reduction technique: (1) the difference method magnifies the error in obtaining the secant velocities, (2) the velocity profile is neither a straight line nor a parabola. To remove these disadvantages, a closed form solution to the equations of motion is used to fit the flight time from the sky screens. A closed form solution is possible when the drag coefficient is assumed to be a linear function of velocity. Therefore, the drag coefficient can also be obtained by fitting the closed form solution to the sky screen data.

ANALYSIS

The equation of motion for a flat fire antitank projectile is

$$M\dot{V} = -\tfrac{1}{2}\rho V^2 S C_D \tag{1}$$

where

M = Projectile mass
V, $\dot{V}$ = Velocity and time rate of change of velocity
ρ = Air density
S = Reference area
C_D = Drag coefficient

When the drag coefficient is a linear function of velocity, having a form of $C_D = C_{D_a}(1 + bV)$, equation 1 becomes

$$M\dot{V} = -\tfrac{1}{2}\rho V^2 C_{D_a}(1 + bV)$$

or

$$\dot{V} = -AV^2(1 + bV) \tag{2}$$

where A is a constant and is defined as $\frac{1}{2M}\rho S C_{D_a}$, and b is a slope value for the linear drag expression. In most cases, b has a negative value.

The closed form solution for velocity as a function of range (x) can be obtained by integrating equation 2 with $V = \frac{dx}{dt}$. The solution is

$$V = V_c(1 + bV)e^{-Ax}$$

or

$$V = \frac{V_c}{e^{Ax} - bV_c} \tag{3}$$

where $V_c \equiv \frac{V_o}{1 + bV_o}$ with the initial condition of $V = V_o$ at $x = 0$.

Furthermore, the closed form solution of t(x) can be obtained from differential equation 3. It has the solution of

$$t = t_o + \frac{1}{AV_c}(e^{Ax} - 1) - bx \tag{4}$$

with the initial condition of $t = t_o$ at $x = 0$.

Equation 4 expresses the projectile flight time as a function of range which is in the form to fit the sky screen data.

To obtain a best fit in the sense of minimizing the squares of the deviations, a residual is defined

$$R_e = \tfrac{1}{2}\sum_{i=1}^{N} (t_{ic} - t_{ie})^2 \tag{5}$$

where t_{ic} is the time of flight calculated from equation 4 and t_{ie} is the time of flight obtained from the sky screen for the projectile to reach the i^{th} sky screen, and N is the total number of sky screens used for that test.

To minimize the residual, equation 5 is differentiated with respect to the four variables (t_o, A, V_o, and b) individually, and then set to zero. They are

$$\begin{aligned}
\frac{\partial R_e}{\partial t_o} &= \sum_{i=1}^{N}(t_{ic} - t_{ie})\frac{\partial t_{ic}}{\partial t_o} = 0 \\
\frac{\partial R_e}{\partial A} &= \sum_{i=1}^{N}(t_{ic} - t_{ie})\frac{\partial t_{ic}}{\partial A} = 0 \\
\frac{\partial R_e}{\partial V_o} &= \sum_{i=1}^{N}(t_{ic} - t_{ie})\frac{\partial t_{ic}}{\partial V_o} = 0 \\
\frac{\partial R_e}{\partial b} &= \sum_{i=1}^{N}(t_{ic} - t_{ie})\frac{\partial t_{ic}}{\partial b} = 0
\end{aligned} \tag{6}$$

The following partial derivatives of t_{ic} with respect to the four variables can be obtained by differentiating equation 4

$$\frac{\partial t_{ic}}{\partial t_o} = 1$$

$$\frac{\partial t_{ic}}{\partial A} = \frac{1}{A^2 V_c}[1 + e^{Ax_i}(Ax_i - 1)]$$

$$\frac{\partial t_{ic}}{\partial V_o} = -\frac{1}{AV_o^2}(e^{Ax_i} - 1)$$

$$\frac{\partial t_{ic}}{\partial b} = (e^{Ax_i} - 1) - x_i \tag{7}$$

With such a complex expression of the four variables in the set of equation 6, the easier approach in solving the four unknown variables is by using the iterative method. To obtain the corrections for the variables from the j^{th} iteration to the $j + 1^{st}$ iteration, the t_{ic} is expanded in a Taylor's Series and the series is truncated after the first order terms. Therefore

$$t_{ic}(j + 1) = t_{ic}(j) + \frac{\partial t_{ic}}{\partial t_o}\Big|_j(\Delta t_o) + \frac{\partial t_{ic}}{\partial A}\Big|_j(\Delta A) + \frac{\partial t_{ic}}{\partial V_o}\Big|_j(\Delta V_o) + \frac{\partial t_{ic}}{\partial b}\Big|_j(\Delta b) \tag{8}$$

Equation 8 is substituted into equation 6 for calculating the $j + 1^{st}$ corrections. For simplicity, the subscript j and j + 1 will be omitted in the following expressions:

$$\frac{\partial R}{\partial t_o} = 0 = \sum_{i=1}^{N}[(t_{ic} - t_{ic})\frac{\partial t_{ic}}{\partial t_o} + (\frac{\partial t_{ic}}{\partial t_o})^2\Delta t_o + \frac{\partial t_{ic}}{\partial t_o}\frac{\partial t_{ic}}{\partial A}\Delta A + \frac{\partial t_{ic}}{\partial t_o}\frac{\partial t_{ic}}{\partial V_o}\Delta V_o + \frac{\partial t_{ic}}{\partial t_o}\frac{\partial t_{ic}}{\partial b}\Delta b]$$

$$\frac{\partial R}{\partial A} = 0 = \sum_{i=1}^{N}[(t_{ic} - t_{ic})\frac{\partial t_{ic}}{\partial A} + \frac{\partial t_{ic}}{\partial t_o}\frac{\partial t_{ic}}{\partial A}\Delta t_o + (\frac{\partial t_{ic}}{\partial A})^2\Delta A + \frac{\partial t_{ic}}{\partial A}\frac{\partial t_{ic}}{\partial V_o}\Delta V_o + \frac{\partial t_{io}}{\partial A}\frac{\partial t_{ic}}{\partial b}\Delta b]$$

$$\frac{\partial R}{\partial V_o} = 0 = \sum_{i=1}^{N}[(t_{ic} - t_{ic})\frac{\partial t_{ic}}{\partial V_o} + \frac{\partial t_{ic}}{\partial t_o}\frac{\partial t_{ic}}{\partial V_o}\Delta t_o + \frac{\partial t_{ic}}{\partial A}\frac{\partial t_{ic}}{\partial V_o}\Delta A + (\frac{\partial t_{ic}}{\partial V_o})^2\Delta V_o + \frac{\partial t_{ic}}{\partial V_o}\frac{\partial t_{ic}}{\partial b}\Delta b]$$

$$\frac{\partial R}{\partial b} = 0 = \sum_{i=1}^{N}[(t_{ic} - t_{ic})\frac{\partial t_{ic}}{\partial b} + \frac{\partial t_{ic}}{\partial t_o}\frac{\partial t_{i}}{\partial b}\Delta t_o + \frac{\partial t_{ic}}{\partial A}\frac{\partial t_{ic}}{\partial b}\Delta A + \frac{\partial t_{ic}}{\partial V_o}\frac{\partial t_{ic}}{\partial b}\Delta V_o + (\frac{\partial t_{ic}}{\partial b})^2\Delta b]$$

$$\tag{9}$$

The set of equation 9 can be written in matrix notation, which is in the form of: $M \cdot \Delta B = C$

where

$$
M = \begin{pmatrix}
\sum_{i=1}^{N} \left(\frac{\partial t_i}{\partial t_o}\right)^2 & \sum_{i=1}^{N} \frac{\partial t_i}{\partial t_o} \frac{\partial t_i}{\partial A} & \sum_{i=1}^{N} \frac{\partial t_i}{\partial t_o} \frac{\partial t_i}{\partial V_o} & \sum_{i=1}^{N} \frac{\partial t_i}{\partial t_o} \frac{\partial t_i}{\partial b} \\
\sum_{i=1}^{N} \frac{\partial t_i}{\partial t_o} \frac{\partial t_i}{\partial A} & \sum_{i=1}^{N} \left(\frac{\partial t_i}{\partial A}\right)^2 & \sum_{i=1}^{N} \frac{\partial t_i}{\partial A} \frac{\partial t_i}{\partial V_o} & \sum_{i=1}^{N} \frac{\partial t_i}{\partial A} \frac{\partial t_i}{\partial b} \\
\sum_{i=1}^{N} \frac{\partial t_i}{\partial t_o} \frac{\partial t_i}{\partial V_o} & \sum_{i=1}^{N} \frac{\partial t_i}{\partial A} \frac{\partial t_i}{\partial V_o} & \sum_{i=1}^{N} \left(\frac{\partial t_i}{\partial V_o}\right)^2 & \sum_{i=1}^{N} \frac{\partial t_i}{\partial V_o} \frac{\partial t_i}{\partial b} \\
\sum_{i=1}^{N} \frac{\partial t_i}{\partial t_o} \frac{\partial t_i}{\partial b} & \sum_{i=1}^{N} \frac{\partial t_i}{\partial A} \frac{\partial t_i}{\partial b} & \sum_{i=1}^{N} \frac{\partial t_i}{\partial V_o} \frac{\partial t_i}{\partial b} & \sum_{i=1}^{N} \left(\frac{\partial t_i}{\partial b}\right)^2
\end{pmatrix}
$$

$$
\Delta B = \begin{pmatrix} \Delta t_o \\ \Delta A \\ \Delta V_o \\ \Delta b \end{pmatrix} \quad \text{and} \quad C \equiv \begin{pmatrix}
\sum_{i=1}^{N} (t_{ie} - t_{ic}) \frac{\partial t_i}{\partial t_o} \\
\sum_{i=1}^{N} (t_{ie} - t_{ic}) \frac{\partial t_i}{\partial A} \\
\sum_{i=1}^{N} (t_{ie} - t_{ic}) \frac{\partial t_i}{\partial V_o} \\
\sum_{i=1}^{N} (t_{ie} - t_{ic}) \frac{\partial t_i}{\partial b}
\end{pmatrix} \tag{10}
$$

The subscript c for the partial derivatives has been omitted. There is no ambiguity because the partial derivatives can only be computed from the closed form solution. The corrections are obtained by inverting matrix M, that is

$$
\Delta B = M^{-1} C \tag{11}
$$

The iteration will be terminated when a prescribed degree of convergence or number of iterations is reached.

DISCUSSION

The computer program listing for this sky screen data reduction technique is shown in appendix A. The sky screen data for round number 63 for the 105-mm APFSDS projectile M833 fired on 20 April 1984 at Aberdeen Proving Ground was chosen as a test case for this data reduction technique. The computer printout for this test case is given in appendix B. The results show that it only took four iterations to achieve the desired convergence even though the initial guessed muzzle velocity and drag coefficient were different by as much as 35% from their best-fit values. Therefore, for reasonably well-behaved sky screen data, this iterative method converges very rapidly.

To investigate the deviation between the path the projectile travelled and the ground distance due to the trajectory curvature, the deviations were calculated for ground ranges of 2,500 meters and 3,000 meters for the 105-mm HEAT projectile M456 and the 105-mm APFSDS projectile M833. The super-elevation needed to reach 2,500 meters for the M456 projectile is 0.84 degree and to reach 3,000 meters for the M833 projectile is 0.41 degree. This deviation is approximately 0.025 meters for the M833 projectile and 0.07 meters for the M456 projectile at their respective ranges. These deviations are within the accuracy of the sky screen data, therefore, the trajectory curvature can be neglected in the data reduction.

CONCLUSIONS

The only limitation of this sky screen data reduction technique is that the drag coefficient has to be a linear function of velocity. From results of some test cases, it indicates that this technique still rendered excellent results, even with the drag coefficient deviating slightly from the linearity requirement.

SYMBOLS

A	Constant, defined as $\frac{1}{2M}\rho SC_{D_a}$, per meter
b	Slope value in drag coefficient expression, per meter per second
C_D	Drag coefficient
C_{D_a}	Constant in drag coefficient expression
M	Projectile mass, kg
ρ	Air density, kg/meter^3
S	Projectile reference area, meter^2
t	Time of flight, seconds
t_o	Time at the gun muzzle, seconds
V	Projectile velocity, meters per second
V_o	Muzzle velocity, meters per second
V_c	Defined as $\frac{V_o}{1 + bV_o}$, meters per second
x	Range, meters
$(\dot{\ })$	Time rate of change, $\frac{d}{dt}(\ )$

<u>Subscript</u>

c	Values computed from the closed form solution
e	Values from range data
i	Values pertaining to the i^{th} sky screen
j	Values pertaining to the j^{th} iteration

APPENDIX A

COMPUTER PROGRAM LISTING

```
      PROGRAM MUZFIT(INPUT,TAPE5=INPUT,OUTPUT,TAPE6=OUTPUT)
      DIMENSION X(16),TE(16),TC(16),TD(16),WXX(5),C(5,6),D(5)
      DIMENSION AA(4),M(16),XX(16),TITLE(8),FF(4)
      DIMENSION R(7),V(7)
      DATA XX/56.81,74.81,92.81,110.8,128.81,239.76,453.22,779.93,
     +982.1,1251.18,1479.0,1741.45,1984.35,2475.85,2733.21,2983.21/
      DATA AA/3HTO=,3HA= ,3HVO=,3HB= /
      DATA FF/.010,.00005,30.,.00005/
      DATA R/0.0,500.0,1000.0,1500.0,2000.0,2500.0,3000.0/
  700 FORMAT(8A10)
  701 FORMAT(16I1)
  702 FORMAT(8F10.2)
   10 READ(5,700) TITLE
      IF(EOF(5) .NE. 0.0) STOP
      READ(5,702) (TE(I),I=1,16)
      READ(5,702) (D(I),I=1,4)
      READ(5,701) M
      L=0
      DO 50 I=1,16
      IF(M(I) .EQ. 0) GO TO 50
      L=L+1
      X(L)=XX(I)
      TE(L)=TE(I)
   50 CONTINUE
      NT=L
  800 FORMAT(1H1)
      WRITE(6,800)
  600 FORMAT(1H0/10X,8A10)
      WRITE(6,600) TITLE
  601 FORMAT(//10X,*NUMBER OF SKY SCREENS =  *,I2)
      WRITE(6,601) NT
      WRITE(6,801)
  801 FORMAT(//10X,*RANGE DATA-METERS*/)
      WRITE(6,602)  (X(I),I=1,NT)
  602 FORMAT( 10X,10F10.3)
      WRITE(6,802)
  802 FORMAT(//10X,*TIME DATA-SECONDS*/)
      WRITE(6,603) (TE(I),I=1,NT)
  603 FORMAT( 10X,10F10.6)
      WRITE(6,803)
  803 FORMAT(///10X,*INITIAL GUESSES--*)
      WRITE(6,604) (D(I),I=1,4)
  604 FORMAT( /10X,F12.6 ,F12.7,F12.2,F12.6)
      NR=0
      E=0.0
  805 FORMAT(//4X,13HITERATION NO.,6X,9HRESIDUALS,7X,14HPROBABLE ERROR
     +//10X,43HCORRECTIONS OF CONSTANTS FOR EACH ITERATION)
      WRITE(6,805)
```

```
  100 SR=0.0
      DO 130 J=1,5
      WXX(J)=0.0
      DO 130 I=1,4
      C(I,J)=0.0
  130 CONTINUE
      TO=D(1)
      A=D(2)
      VO=D(3)
      B=D(4)
      VC=VO/(1.0+B*VO)
      AVC=A*VC
      AAVC=A*AVC
      VC2=VC**2
      VO2=VO**2
      DO 150 I=1,NT
      AX=A*X(I)
      EAX=EXP(AX)
      EAX1=EAX-1.0
      PTA=(-EAX1+EAX*AX)/AAVC
      PTV=-EAX1/(A*VO2)
      PTB=(EAX1-AX)/A
      TC(I)=TO+EAX1/AVC-B*X(I)
      TD(I)=TE(I)-TC(I)
      SR=SR+TD(I)**2
      C(1,1)=C(1,1)+1.0
      C(2,1)=C(2,1)+PTA
      C(3,1)=C(3,1)+PTV
      C(4,1)=C(4,1)+PTB
      C(1,2)=C(2,1)
      C(2,2)=C(2,2)+PTA**2
      C(3,2)=C(3,2)+PTA*PTV
      C(4,2)=C(4,2)+PTA*PTB
      C(1,3)=C(3,1)
      C(2,3)=C(3,2)
      C(3,3)=C(3,3)+PTV**2
      C(4,3)=C(4,3)+PTV*PTB
      C(1,4)=C(4,1)
      C(2,4)=C(4,2)
      C(3,4)=C(4,3)
      C(4,4)=C(4,4)+PTB**2
      C(1,5)=C(1,5)+TD(I)
      C(2,5)=C(2,5)+TD(I)*PTA
      C(3,5)=C(3,5)+TD(I)*PTV
      C(4,5)=C(4,5)+TD(I)*PTB
  150 CONTINUE
      NR=NR+1
      E1=E
```

```fortran
      E=0.6745*SQRT(SR/(NT-4))
      WRITE(6,605) NR,SR,E
  605 FORMAT(//10X,I2,2F20.8)
      IF(ABS(E1-E)-1.0E-05) 200,200,110
  110 IF(NR-15) 120,120,200
  120 CALL INV(C,4,5,WXX)
      DO 180 I=1,4
      F=C(I,5)
      IF(ABS(F) .GT. FF(I)) F=SIGN(FF(I),F)
      D(I)=D(I)+F
  180 CONTINUE
      WRITE(6,606) (C(I,5),I=1,4)
  606 FORMAT(/10X,5E18.6)
      GO TO 100
  200 CONTINUE
      CALL INV(C,4,4,WXX)
      DO 210 I=1,4
  210 WXX(I)=SQRT(ABS(C(I,I)))*E
  806 FORMAT(//22X,15HBEST-FIT VALUES,4X,14HPROBABLE ERROR)
      WRITE,(6,806)
      DO 230 I=1,4
  230 WRITE(6,607) AA(I),D(I),WXX(I)
  607 FORMAT(/10X,A3,5X,2E18.6)
  804 FORMAT(//13X,13HRANGE-METERS ,13HTIME-OBS-SEC ,13HTIME-CAL-SEC
     *12HTIME-DIF-SEC//)
  608 FORMAT(10X,F13.2,F13.6,F13.6,F13.6)
      WRITE(6,804)
      DO 240 I=1,NT
      WRITE(6,608) X(I),TE(I),TC(I),TD(I)
  240 CONTINUE
      V1=D(3)+D(1)*D(2)*D(3)**2*(1.0+D(3)*D(4))
      WRITE(6,609) V1
  609 FORMAT(//10X,*MUZZLE VELOCITY AT TIME EQUAL TO ZERO IS *,F10.2)
      V(1)=D(3)
      VC=D(3)/(1.0+D(4)*D(3))
      DO 250 I=2,7
      VAX=VC*EXP(-D(2)*(I-1)*500.0)
      V(I)=VAX/(1.0-D(4)*VAX)
  250 CONTINUE
      WRITE(6,610) R
      WRITE(6,611) V
  610 FORMAT(/5X,15HRANGE(METERS) =,7F12.1)
  611 FORMAT(5X,15HVELOCITY(MPS) =,7F12.1)
      GO TO 10
      END
```

```
      SUBROUTINE INV(C,NC,NCS1,WXX)
      DIMENSION C(5,6),WXX(5),PIVOT(2),CC(5,10)
      NCT=NC*2
      NCP1=NC+1
      DO 10 I=1,NC
      DO 10 J=1,NC
   10 CC(I,J)=C(I,J)
      DO 20 I=1,NC
      DO 20 J=NCP1,NCT
   20 CC(I,J)=0.0
      DO 30 I=1,NC
   30 CC(I,NC+I)=1.0
      DO 205 I=1,NC
      PIVOT(1)=CC(I,I)
      DO 200 K=1,NC
      PIVOT(2)=CC(K,I)
  126 IF(K-I) 135,130,140
  130 DO 150 J=1,NCT
      IF(PIVOT(1)) 134,210,134
  134 CC(K,J)=CC(I,J)/PIVOT(1)
  150 CONTINUE
      GO TO 200
  135 DO 160 J=1,NCT
      IF(PIVOT(1)) 136,160,136
  136 CC(K,J)=CC(K,J)-CC(I,J)*PIVOT(2)/PIVOT(1)
  160 CONTINUE
      GO TO 200
  140 DO 170 J=1,NCT
      IF(PIVOT(2))  145,170,145
  145 CC(K,J)=CC(K,J)/PIVOT(2)-CC(I,J)
  170 CONTINUE
  200 CONTINUE
  205 CONTINUE
      GO TO 250
  210 WRITE(6,600)
  600 FORMAT(//10X,*DET IS EQUAL ZERO*)
  250 DO 300 I=1,NC
      DO 300 J=1,NC
  300 C(I,J)=CC(I,J+NC)
      NCS=NCS1
  350 IF(NCS-NC) 500,500,400
  400 DO 420 I=1,NC
      WXX(I)=C(I,NCS)
  420 C(I,NCS)=0.0
      DO 450 I=1,NC
      DO 450 J=1,NC
  450 C(I,NCS)=C(I,NCS)+C(I,J)*WXX(J)
      NCS=NCS-1
      GO TO 350
  500 CONTINUE
      RETURN
      END
```

APPENDIX B

COMPUTER OUTPUT EXAMPLE

M833 RD-63 20 APRIL 1984

NUMBER OF SKY SCREENS = 16

RANGE DATA-METERS

56.810	74.810	92.810	110.800	128.810	239.760	453.220	779.930	982.100	1251.180
1479.000	1741.450	1984.350	2475.850	2733.210	2983.210				

TIME DATA-SECONDS

.019120	.031357	.043615	.055684	.068176	.144037	.291479	.517793	.659608	.850710
1.013619	1.202379	1.379403	1.743115	1.935780	2.126484				

INITIAL GUESSES--

-.010007 .0001000 1420.00 -.000450

ITERATION NO. RESIDUALS PROBABLE ERROR

CORRECTIONS OF CONSTANTS FOR EACH ITERATION

1	.03476655	.03630547		
	-.962418E-02	.333420E-04	.481413E+02	-.881337E-04
2	.00562211	.01459960		
	-.333491E-06	.219809E-05	.195644E+02	-.131498E-04
3	.00000128	.00022051		
	-.814364E-07	.270118E-06	.266375E+00	.237251E-07
4	.00000108	.00020221		
	-.105127E-07	.311720E-08	-.105189E-03	-.460922E-08

	BEST-FIT VALUES	PROBABLE ERROR
T0=	-.196246E-01	.139928E-03
A=	.135813E-03	.2[illegible]9134E-04
V0=	.146983E+04	.971986E+00
B=	-.513131E-03	.314583E-04

RANGE-METERS	TIME-OBS-SEC	TIME-CAL-SEC	TIME-DIF-SEC
56.81	.019120	.019063	.000057
74.81	.031357	.031336	.000020
92.81	.043615	.043617	-.000002
110.80	.055884	.055898	-.000014
128.81	.068176	.068201	-.000025
239.76	.144037	.144156	-.000119
453.22	.291479	.291105	.000374
779.93	.517793	.518159	-.000366
982.10	.659608	.660004	-.000396
1251.18	.850710	.850444	.000266
1479.80	1.013619	1.013203	.000416
1741.45	1.202379	1.202492	-.000113
1984.35	1.379403	1.379445	-.000042
2475.85	1.743115	1.742932	.000183
2733.21	1.935780	1.936293	-.000513
2983.21	2.126484	2.126212	.000272

MUZZLE VELOCITY AT TIME EQUAL TO ZERO IS 1468.42

RANGE(METERS) =	0.0	500.0	1000.0	1500.0	2000.0	2500.0	3000.0
VELOCITY(MPS) =	1469.8	1444.9	1419.1	1392.5	1365.1	1337.0	1306.1

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